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The Management of Airport Noise:

Project Summary and Guidelines for Managers

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The Management of Airport Noise: Project Summary and Guidelines for Managers

by

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16. Abstract

Airport noise challenges airport managers in an era of rapid demand increases and capacity shortages. The demand for noise management reflects the costs it imposes on an airport's neighbours. Hedonic price estimates measure these costs as average discounts of property values per unit increase in the Noise Exposure Forecast. Regression analysis of noise complaints made to Pearson International Airport shows that the probability of complaints from a neighbourhood increases significantly with the Noise Exposure Forecast. The effect is moderated by housing age. Surveys, contingent valuation, and conjoint analysis are presented as other methods to understand various aspects of the public's demand for noise control. Current noise management employs technical requirements, land use guidelines, and various pricing and noise allocation schemes to control noise. Rational guidelines for selecting strategies at an airport are shown to depend on the characteristics of noise that a strategy affects. Qualitative models of the benefits and costs of each strategy are advanced to assist in the choice of a noise control program. Noise is discussed as a common property problem to highlight the potential benefits of pricing of airport resources to fully capture the costs of airport operations.

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16. Résumé

À une époque où la demande de services aéroportuaires croît sans cesse et où les ressources disponibles diminuent, le bruit causé par les aéroports constitue un problème épineux. Les pressions exercées pour obtenir l'atténuation de ce bruit sont à la mesure du coût qu'il impose aux riverains. L'analyse de la valeur d'une maison par la méthode dite hédonistique permet d'exprimer ce coût en termes de diminution moyenne dans la valeur des habitations par unité d'augmentation du bruit, tel qu'indiqué par les courbes de prévision d'ambiance sonore. L'analyse de régression concernant les plaintes au sujet du bruit causé par l'aéroport Pearson montre que plus l'exposition au bruit croît, plus il est probable que le nombre de plaintes ira croissant. Mais l'âge des habitations a pour effet de tempérer cette relation. Il existe d'autres techniques : sondages, analyse conditionnelle de la valeur et analyse conjointe, permettant de mieux saisir les divers aspects des plaintes du public. Les programmes de gestion du bruit font appel à diverses techniques, notamment les lignes directrices concernant les plans d'occupation des sols ainsi que la modulation de la redevance d'atterrissage en fonction de l'intensité du bruit. Le rapport montre que, pour être rationnelle, la sélection des stratégies à mettre en oeuvre doit prendre en compte la nature de la gêne que l'on veut éliminer. Le rapport propose des modèles d'analyse qualitative du rapport avantages-coûts dégagé par chacune des stratégies envisagées pour aider dans le choix de la plus avantageuse parmi elles. Le bruit est traité comme un problème de bien commun afin de mieux faire ressortir l'avantage qu'il a à adjuger les ressources d'un aéroport à leur juste prix afin de pouvoir récupérer les coûts de son exploitation.

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SUMMARY

Current and future demand increases in the air transport industry will be reflected in demand for more runways and terminals and more landings and departures over the day. As increased airport capacity and utilization satisfy these demands, changes in the level of airport activity will generate changes in the levels of "annoyance" effects, including noise pollution, air pollution, ground traffic congestion, and incompatible land use mixes.

This study's goals included the examination of the significance of airport noise as a management problem, the identification of noise management policies and strategies worldwide, and the development of an economic framework for the evaluation and selection of noise strategies.

Examination of recent airport movement statistics worldwide shows that management of the tradeoffs between increased utilization of airport resources and higher levels of annoyance is becoming a crucial aspect of airport administration. This is particularly so because the perceived distribution of benefits and costs of increased airport use involves two relatively different groups. An airport's residential neighbours typically do not see themselves as the beneficiaries when a runway is added or a late night flight is instituted while most of the direct beneficiaries, the flying public, are not so geographically concentrated. The reconciliation of the conflict between these groups is increasingly a key to the successful operation of the modern airport.

Most countries do not have formal noise policies. Only the United States recognizes aircraft noise as a public problem. Numerous statutes in many countries concern noise as a general problem but do not allude specifically to aircraft noise. Two important exceptions are Japan and Germany, which have several laws aimed specifically at aviation noise. Responsibility for noise falls on most national governments through Aviation or Aeronautics Acts. Often, however, local control over land use and zoning thwarts the ability of the national transportation authorities to apply consistent effective noise management policies.

Existing noise abatement and mitigation policies are a product of interactions of members of the aviation field, various levels of government, the aircraft industry, airport operators, and community residents. They include technical requirements like Stage III adoption and building code restrictions, land use restrictions, compensation schemes, and various noise allocation and pricing schemes. It is notable that there is little uniformity in the adoption of various approaches to noise control, and that local concerns and management expertise are key factors in determining what managers do about noise.

Making decisions regarding noise reduction strategies is more difficult than other investment decisions. The economics literature on the common property problem provides some insight about why this is so. The absence of a market and, hence, a market price for noise, and the distinction between noise producers and consumers mean that too much noise will be produced unless some strategy to regulate it is undertaken. The extent of this

regulation must depend on the benefits it yields in noise reduction. An essential step in making strategic decisions, therefore, is the monetary measurement of noise. This facilitates the quantification of the social costs of different levels of noise and permits a more complete measure of the total marginal costs involved in undertaking various courses of action. These costs can then be compared to marginal benefits and the various strategies analysed in an economic framework.

Hedonic price estimation provides a statistical method for valuing the characteristics of a house. A study of over 3 000 real-estate transactions in 1987 in the vicinity of Pearson International Airport shows that exposure to airport noise reduces housing values by an average $1 750 per five decibels of the Noise Exposure Forecast. This finding corroborates the evidence of similar studies that find that airport noise reduces real-estate values. More importantly, the estimate provides a measure of the value of quiet for use in benefit/cost analyses of noise management decisions.

Regression analysis of noise complaints to Pearson International Airport shows that the probability of complaints from a neighbourhood is significantly increased by increased noise exposure. Housing age increases this effect when other socio-economic influences are controlled. This finding constitutes indirect evidence of the importance of housing construction in noise attenuation. Had housing age been found not to be important, then noise strategies based on upgrading sound insulation would probably not address the annoying aspects of noise effectively.

Noise management exhibits a "technology" because different strategies affect different aspects of noise. The potential of a strategy to satisfy the demand for quiet depends on how well its effects correspond to the aspects of noise that the public finds most annoying. If frequency of noise events is significantly more important than sound duration, strategies that do not emphasize scheduling are not likely to succeed. An analysis of alternative noise strategies requires consideration of factors that influence noise annoyance, and assessment of the effects of noise management strategies on these factors. Survey techniques, statistical complaint analysis, and conjoint analysis are described as methods for examining the factors that make noise annoying. Noise management strategies in use worldwide are then characterized concerning their effects on several key aspects of noise.

The results of the project suggest the following observations and recommendations regarding noise management. First, four general objectives which noise management strategies should address: provide benefits in reasonable proportion to the costs households incur; target solutions appropriately; share costs of noise management strategies equitably; and distinguish short-term from long-term initiatives. Second, noise valuation should be the basis for noise management strategies and policy. The ranking of these strategies in meeting the goals of noise management should be based on the proportional contribution to costs. Third, noise measures are not an end in themselves but represent a means of defining noise exposure areas. The measures should not, therefore, be technically based but rather have a behavioural foundation. They should measure people's and markets' response to noise, not

just noise itself. Fourth, an airport has a noise capacity just as it has an operational capacity and this concept is central to the solution to the noise problem. Since this capacity is a scarce resource it should be sold or auctioned to the airlines at prices that reflect this value, rather than being given away. Fifth, the following must be considered in developing workable noise management strategies: political precedent versus effectiveness, fairness versus efficiency, and effectiveness versus simplicity. Sixth, the appropriate ranking of the three alternative approaches to solving the noise problem are compensation, noise mitigation and noise reduction. Finally, the airport is a community asset and not simply a cost to the community. It provides benefits as well as costs. In order to realize its full potential, a community relations program is a vital part of any noise management scheme.

TABLE OF CONTENTS

SECTION 1:	**GENERAL INTRODUCTION**	1
SECTION 2:	**EXTERNALITIES: A STRATEGIC PROBLEM FOR AIRPORTS**	2
	2.1 Introduction	2
	2.2 Model for a Managerial Response to Externalities	4
SECTION 3:	**AIRPORT NOISE**	9
SECTION 4:	**MEASURING THE NOISE PROBLEM**	13
SECTION 5:	**CURRENT STATE OF NOISE MANAGEMENT**	15
	5.1 Introduction	15
	5.2 The Airport Setting	15
	5.3 Effects of Strategies on Noise	18
SECTION 6:	**RECOMMENDATIONS**	30
REFERENCES		35

LIST OF TABLES

Table 1: Canadian Airport Traffic Actual and Forecast 3

Table 2: Airlines' Strategic Response to Noise Management Strategies 6

Table 3: Noise Matrix 21

Table 4: Impact of Noise Strategies on Single-Event and Cumulative Noise Levels 22

Table 5: Noise Management Strategies: Benefits, Reduction, Costs and Comments 24

LIST OF FIGURES

Figure 1: Major "Players" and Transactions that Affect Airport Management 5

Figure 2: The Probability of Complaints 7

Figure 3: Noise Metrics and Applications 10

Figure 4: Typical Noise Annoyance Question 11

Figure 5: Dose Response Curve 12

Figure 6: Questions that Examine the Dimensions of Noise Annoyance 14

Figure 7: Airport Typology Framework 16

Figure 8: Short-Term and Long-Term Strategy Selections 18

SECTION 1
GENERAL INTRODUCTION

Environmental spillovers from airport operations challenge airport managers. This is especially the case for airport noise. Airport neighbours increasingly oppose management's capacity expansion plans in their efforts to contain noise exposure. Their access to formal environmental hearings forces airport management to deal with the conflicting demands of airlines, their customers and the airport's neighbours. Airport managers find themselves "caught in the middle" of those who demand solutions to airport congestion and those who demand solutions to noise. Effective noise management requires strategies that balance the needs of airport owners, airlines and their customers, and the airport's neighbours.

This project summary and manager's guide contributes to the formulation of noise management strategies in four ways:

- It discusses the nature and significance of airport externalities. Airport externalities present potential obstacles to the flexible management of an airport's resources. Overcoming them is first a matter of understanding how they arise.
- It identifies the main "players" and reviews their interests. Noise management is not simply a technical problem. Other decision-makers react to noise management according to the costs involved. Management must understand these reactions, especially if they restrict its potential to act.
- It defines a noise management "technology" based on several aspects of airport noise. It lists a variety of noise management strategies, and summarizes how each affects noise.
- It characterizes the potential benefits and costs of each strategy. This feature of the report provides a basis for a rational evaluation of alternative noise management strategies.

A full explanation of the nature and assessment of noise externalities and the formation of management strategies can be found in *The Management of Airport Noise*, report prepared for the Transportation Development Centre by DWG Research Associates Ltd. This document together with Technical Reports is available in Transport Canada libraries in Montreal and Ottawa.

SECTION 2
EXTERNALITIES: A STRATEGIC PROBLEM FOR AIRPORTS

2.1 Introduction

Airport noise is an example of an externality. An externality is a by-product of production or consumption that benefits or costs someone who has no direct control over its presence. When your neighbours cut their lawns you are a beneficiary if the appearance of the neighbourhood matters to you. Passive cigarette smoking on airplanes imposes a costly spillover on its recipients. When an airport's neighbours awaken to aircraft noise, they incur a similar cost without any direct control over how large it will be.

Externalities create a strategic problem for an airport's manager because the recipients can retaliate. For example, the decision to reschedule movements to one runway while another undergoes repair typically produces increased public complaints about noise. The strategic significance of the externality problem depends directly on the seriousness of the retaliation that might arise. An assessment of the needs and potential for retaliation of the "players" in an airport's environment represents a crucial step in the development of a noise strategy.

At issue in the dispute between an airport's neighbours and its customers is the level of use of a common property resource – the surrounding physical environment. Demands of landowners who face expropriation, complaints about noise, and political opposition to expansion plans influence the feasibility of increasing airport services. Expropriation costs reduce the profitability of expansion investment. Political forces can reduce the probability that regulators allow expansion at all. Both demands, then, are expressions of a " supply price" for a resource that the airport needs.

An airport's customers similarly value the use of the surrounding environment but for different reasons. Their "demand price" is the maximum that they would be willing to pay to use the resources of the airport as a transportation facility. In the absence of a market in which both sides can agree about how noisy airport activity will be, the airport's owners and managers must provide strategies that coordinate the demands of its neighbours and its customers. Otherwise they will face the obstacles and constraints that arise when one side acts on its dissatisfaction.

Airports in North America, Europe and Asia are experiencing extraordinary pressures to accommodate increased traffic by adding more slots and runways. Simultaneously, a general demand for more environmental responsibility is forcing airports to listen to and deal with groups affected adversely by airport externalities. The urgency of the congestion problem coupled with this environmental awareness is increasing the public's strategic leverage in approval processes. This leverage could have a significant negative impact on the

rationalization of the worldwide air transportation system. Airport managers must respond by adopting comprehensive noise strategies that balance the demands of their customers and their neighbours.

An airport's neighbours have gained increasing strategic power for several reasons. Many airports' interest in capacity expansion has never been higher. Congestion and unabated growth in demand for air transportation (see Table 1) have increased the potential costs of failing to implement successful capacity expansion plans. This makes the threat posed by dissatisfied airport neighbours considerably more important than it would be if the industry were experiencing no growth.

Table 1

Canadian Airport Traffic
Actual and Forecast*

Year	Vancouver		Winnipeg		Toronto		Dorval		Mirabel	
	pax.	move.	pax.	move.	pax.	move.	pax.	move.	pax.	move.
1983	6437	222.7	1871	130.0	13865	238.3	5372	149.7	1304	46.1
1984	6620	211.0	1954	137.0	15012	257.0	5821	156.9	1483	51.5
1985	6714	205.6	1967	147.0	15923	283.4	5705	152.7	1733	52.4
1986	8185	278.8	2068	145.0	17136	301.2	5759	159.6	2052	43.3
1987	†	302.6	2100	148.0	18602	316.3	†	†	†	†
1988	†	366.9	2300	152.0	20632	348.4	†	170.8	†	†
1996*	11860	412.0	3436	133.0	25000	404.0	8590	247.0	3440	62.0
2001*	13720	436.0	4074	149.0	30110	449.0	9850	277.0	4220	74.0

pax. = number of passengers enplaned and deplaned in 1000s
move. = number of movements in 1000s
† = not available

Sources: ICAO (International Civil Aviation Organization): 1983-88
Transport Canada Aviation Forecasts: 1996, 2001

Airport managers are responsible for operating an airport in the interests of its owners. Rational management practice requires them to make decisions that can be justified on a benefit/cost basis. Failure to anticipate retaliation and manage accordingly means that the full costs of a decision are unaccounted for, because retaliation can impair management's ability to optimize the use of the airport.

A common response to noise complaints in the past denied that noise generates costs, and focussed instead on progress and economic benefits derived from more intensive use of airport resources. Nevertheless, noise is costly, and not just as it negatively affects an airport's neighbours. To the extent that these neighbours have any strategic leverage, they can delay or block indefinitely socially efficient increases in airport capacity.

Growing public awareness and acknowledgement of negative externalities like air and water pollution have moved the resolution of externality problems to the front of the political agenda. It is easier today for opponents of airport expansion to use the political system by participating in environmental impact hearings and electoral politics. Even if an airport's managers are not under pressure to expand, they face a greater strategic challenge based on their environmental roles.

Management's "middle ground" role depends on its responsibility to its owners to run their airport as efficiently as possible. Management must develop strategies to deal with spillover problems if they represent potential impediments to the attainment of this objective. An airport's particular circumstances will determine the threat and the appropriate response. Whatever the response, it is best determined by a rational assessment of the problem, including a benefit/cost analysis of alternative strategies.

2.2 Model for a Managerial Response to Externalities

A framework to address the problem of externalities management must do three things:

- Assist management to approach the externality problem systematically and to provide defensible results;
- Suggest the data and information that management will require to analyse alternative options for externality management;
- Incorporate an evaluation scheme for making selections among the feasible options.

To begin, it is important to consider the "players" that have a role in the noise problem, their motivations and the transactions between them that relate to the management of the externality. This analysis should indicate the importance of responding to the externality, and what constraints related to noise hinder management. It should also anticipate the reactions that management can expect to any strategies that they might adopt.

Figure 1 presents a "generic" model of the "players" and their connections. The "supply" of noise depends on the transactions between airlines and their customers in the air travel market, and the transactions between airlines and airports in the "market" for slots. The amount of noise increases as the activity in either of these markets increases.

Major "Players" and Transactions that Affect Airport Management

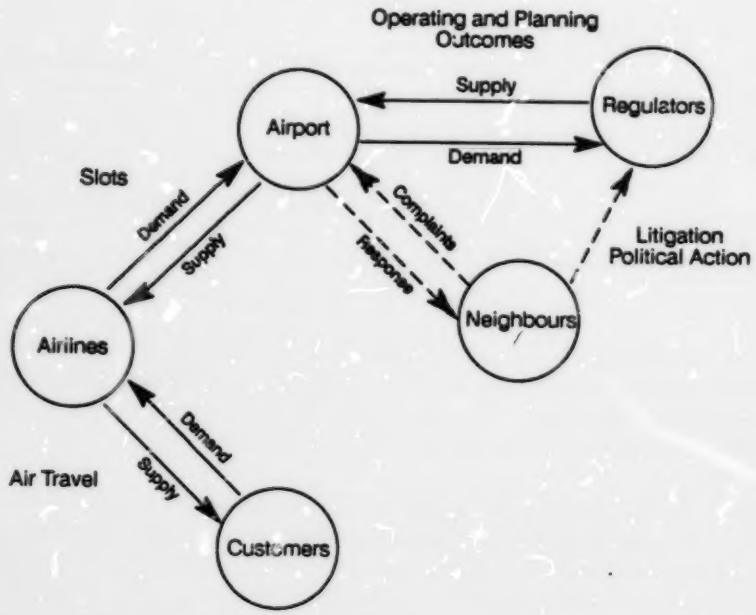

Figure 1

Noise management strategies that impose costs on the suppliers of noise will affect their demands. An airport, for example, raises airlines' costs of using airport facilities if it requires that carriers upgrade fleets to Stage III standards. It also raises their costs if it taxes carriers to support noise abatement, or if it fines them for noise violations. Carriers will respond to such cost increases by adjusting their use of the airport in direct relation to the accessibility of a lower-cost alternative, and to how much of these costs they can pass on to customers.

Carriers' demands for slots will not change much if there are no substitute airports available or if they are able to pass cost increases on to their customers easily. Their response and the amount of noise depend on how easily they can adjust to rising costs by using other facilities or raising their prices.

Airlines' strategic response to rising costs of noise management will depend on their flexibility. The more easily they can avoid the financial impact, the less reason they will have for resisting noise management strategies. Table 2 depicts the relationship between the opportunities that airlines have to avoid the costs imposed by noise management strategies and their likely response.

Table 2

Airlines' Strategic Response to Noise Management Strategies

	Close, lower-cost airports	No close, lower-cost airports
Easy to pass costs on to customers	Stay, pass costs on to customers, threaten to leave	Stay, pass costs on to customers, no resistance
Hard to pass costs on to customers	Move to lower-cost site	Stay, fight the imposition of the costs

Increased activity generates more noise, but it simultaneously provides increased revenues for the airport's operators. Additionally, it produces economic benefits in terms of employment and expenditure for the local community. This point cannot be overlooked without overstating the size of the noise problem.

Reduction of noise carries both benefits and costs that must be equally assessed in the development and implementation of noise management strategies. Even when a public authority operates an airport "in the public interest," it is wrong to evaluate the consequences of noise management strategies without accounting for any reduction in benefit to others whose welfare depends on the utilization of the airport's infrastructure. Just as too much noise can arise from failure to account for its real costs, failure to include the benefits of airport operations can result in too little airport activity. It is crucial in evaluating responses to noise to assess all the effects of a strategy.

The demand for quiet arises mainly from residents of neighbourhoods close to an airport. However, employees of businesses and school boards that are affected by airport operations during normal working hours may also have a stake in noise management. The collective demands of these groups depend on a number of factors. Studies of noise complaints indicate that the amount of noise is the most significant determinant of this expression of demand for quiet.

Figure 2 shows a relationship between the probability of complaints and the Noise Exposure Forecast (NEF) based on data provided by Pearson International Airport. The age of housing modifies the relationship. Newer construction and better sound insulation appear to reduce the probability of complaints at any level of noise exposure.

Other studies suggest that the public's understanding of the airport's role in their community and its efforts to accommodate everyone's needs affect their reaction to airport noise. People are less likely to complain and engage in strategic retaliation when they believe that the airport's management is acting in good faith to deal with their concerns.

The Probability of Complaints
NEF vs Housing Age

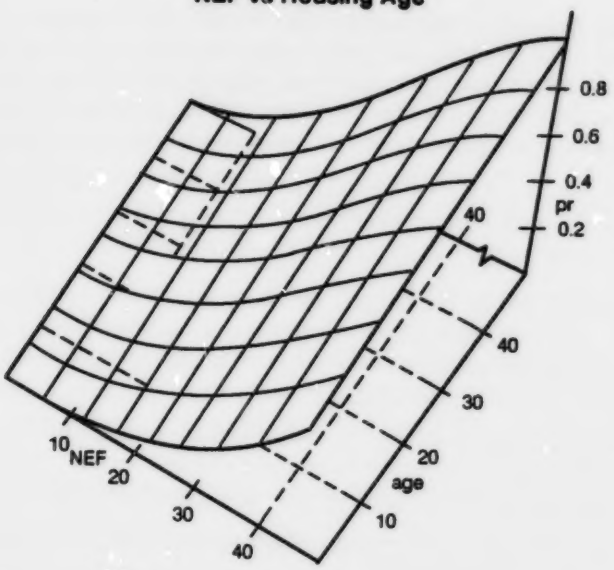

Figure 2

Source: DWG Research Associates Ltd., *The Management of Airport Noise,* TP 10118E, Report to Transportation Development Centre (1990).

The costs of organizing efforts to articulate demands for noise reduction represent an obstacle to strategic retaliation by residents and others affected by noise. The more difficult it is for them to use political and regulatory channels to express their demands, the less strategically significant their demand for noise management will be. It is important to note that lack of action does not mean lack of demand for quiet. Conditions may change – for example, an election may be called – leading to the empowerment of those interested in noise reductions.

Noise reductions come from two sources. Voluntary reductions by airlines are possible but less likely than enforced reductions regulated by airports, governments or courts. An analysis of the strategic significance of each of these agencies assists airport managers in understanding the extent of external pressure for effective noise management. Managers should at least list each type of agency and its policies concerning airport operations. Also, an assessment of the responsiveness of each agency to the noise problem can provide insight into outside influences, especially in this era of increasing environmental awareness.

To summarize, an effective approach to noise management begins with an assessment of the "environment," including an examination of the relevant "players."

- Airlines and their customers must be considered because noise is a by-product of their demands for the airport's services. How sensitive is this demand to changes in the costs of using the airport? How much strategic leverage do they have to resist attempts to make them bear the costs of noise management? How much do they understand the management problem that noise creates for airports?
- Airports must consider their objectives, responsibilities and resources and how these relate to noise management. How are they placed strategically relative to airlines and their customers, their neighbours and the regulators?
- Neighbours' demands for quiet must be considered in order to determine the seriousness of the noise problem. How does noise affect them? How do they react to it? What strategic advantages do they have in articulating their demands for noise management?
- The influence of general concern for environmental issues must be assessed. How are the political and legal systems affected by these concerns, and how is this likely to affect the restrictions placed on airport operations in the future?

A report on each of these elements provides management with a context for making decisions on noise management. This is critical for establishing the gravity of the problem, the strategic costs of attempts to deal with it and the approaches that might be used to avoid them.

SECTION 3
AIRPORT NOISE

Noise is simultaneously two phenomena. The acoustician characterizes noise technically in terms of physically measured sound pressure levels. In the noise management context, noise also describes the physiological, psychological and behavioural responses of the listener to the physical phenomenon. Differential weighting of day and night noise events in the calculation of cumulative noise measures recognizes this dual nature of noise. For instance, the NEF weights night noise 16.67 times more heavily than day events. However, time of day weighting does not reflect the complex nature of noise completely, and this has affected previous noise management strategy.[1]

An official group of noise metrics has been established for measuring and technically evaluating noise for land use planning and environmental impact assessment. To control aircraft noise at the source, the Federal Aviation Administration (FAA) employs a second system of metrics for aircraft certification. The noise metrics used most often in North America can be separated into four general categories:[2]

1. Single Event Maximum Sound Levels: ALm, PNL, PNLT
2. Single Event Energy Dose: SENEL, EPNL
3. Cumulative Energy Average Metrics: Leq, Ldn, CNEL, NEF
4. Cumulative Time Metrics: TA

Within and between categories there is some bridging of the noise metrics by either definition or mathematics. The various noise metrics employed in assessing noise are presented in Figure 3. The two most common measures seen in Canada are NEF and (to a lesser extent) Ldn.[3] The Day-Night sound level (Ldn) is a single number measure of community noise. The Ldn value, which has been A-weighted, is employed as a predictor of the effects of cumulative aircraft noise on the airport environs. In Ldn measurements, the noise generated from each aircraft takeoff or landing at ground level is calculated and accumulated for a 24-hour period. Because of increased sensitivity to noise during nighttime hours, daytime and nighttime exposures are treated separately with nighttime (22:00-07:00) allocated a 10 dB penalty. The Ldn has frequently been reassessed during its 30 years of use.

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[1] *A complete description of types and methods of noise measurement can be found in DWG Research Associates Ltd., "The Management of Airport Noise", TP 10118E, Report to Transportation Development Centre, Montreal (1990).*

[2] *Material drawn from "Aviation Noise Effects", U.S. Department of Transportation, FAA, 1985 and DWG Research Associates Ltd., "The Management of Airport Noise", TP 10118E, Report to Transportation Development Centre, Montreal (1990).*

[3] *Ldn is approximately equal to NEF-35. Both are highly responsive to changes in noise energy level and change relatively little with small to moderate changes in frequency of flights.*

Noise Metrics and Applications

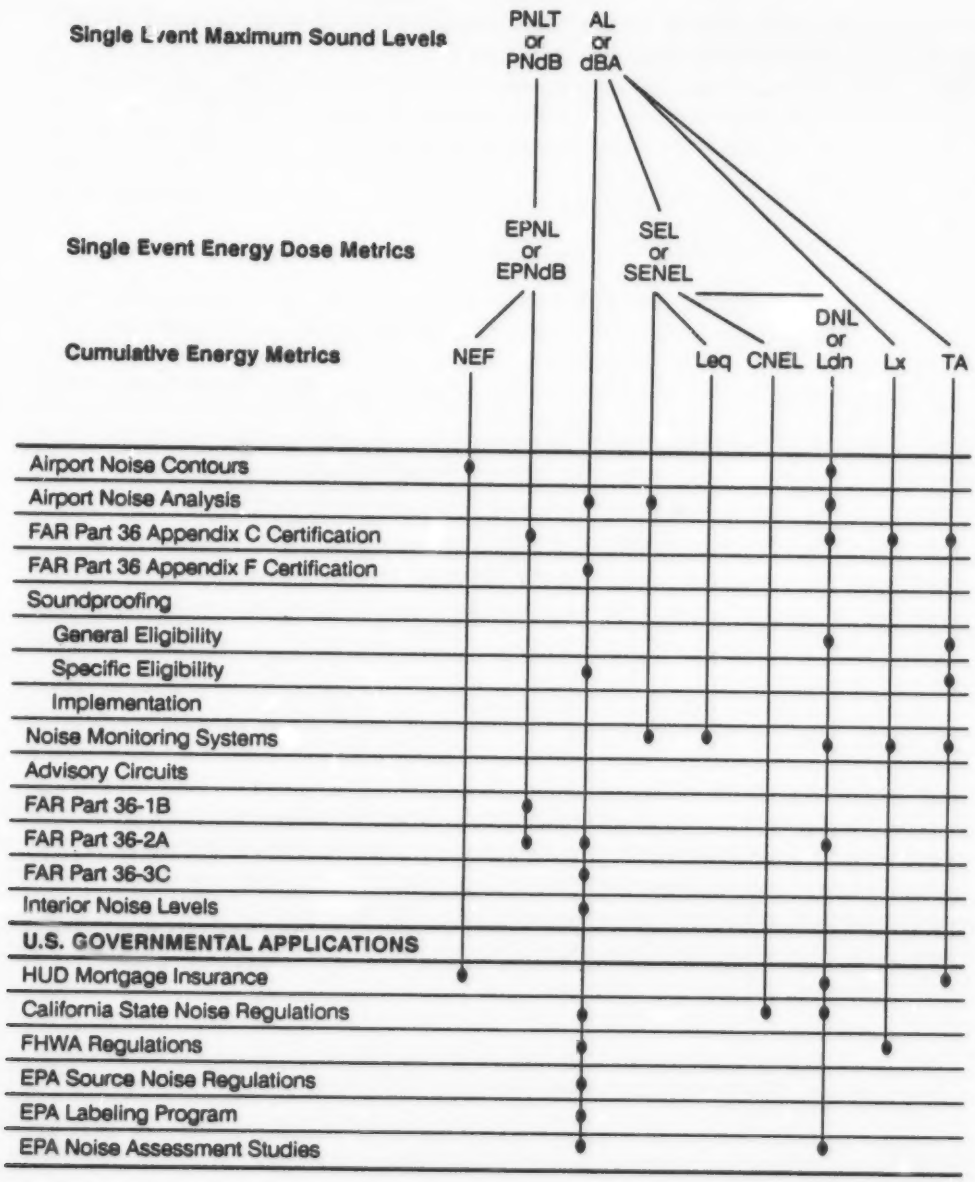

Figure 3

The NEF uses individual aircraft source noise expressed in EPNL (EPNdB) over a 24-hour period, weighted for the time of day. To calculate NEF at a specific location, the noise contribution from each aircraft operating from each runway is assessed by considering the distance from the point in question to the aircraft and then obtaining EPNdB (the decibel rating in the EPN scale) values from the appropriate SPNdB (the decibel rating in the SPN scale) vs distance curve. The noise contributions of all aircraft operating on all runways are summed on an antilog basis to obtain the total noise exposure at that one location. Noise contours of airport environs can be calculated by joining points of equal NEF value. Calculation of these values requires information on the number of operating aircraft, the type of aircraft, the individual noise characteristics of the aircraft, flight path data, time of flight and the flight operating procedures of the pilot.

Noise should be measured using a behavioural index. In the past, noise management has focussed on reducing noise annoyance as measured by survey responses to questions such as that in Figure 4. Researchers attempted to calibrate responses to this question to noise measures such as the NEF. They plotted the proportion of the respondents reporting "very annoyed" against the NEF recorded at their residences. This exercise yielded dose response curves similar to that in Figure 5.

Typical Noise Annoyance Question

How annoyed are you by aircraft noise?

a) not annoyed
b) a little annoyed
c) rather annoyed
d) very annoyed

Figure 4

The dose response curve yields a gross indicator of the effects of noise reduction on stated annoyance. As such it creates an impression of the "noise problem" for an airport. Dose response analysis can be combined with a census of the population to measure the potential size of the opposition to airport noise.

Beyond the size of the opposition, dose response analysis does not provide much insight to managers seeking to choose an effective noise management strategy. The effect of airport noise on the individual is complex and cannot be captured by responses to a single question like the one in Figure 4. Noise annoyance depends on a variety of psychological variables and the context of the noise disturbance, in addition to its acoustical properties.

Dose Response Curve

(Proportion of respondents reporting "very annoyed" vs NEF)

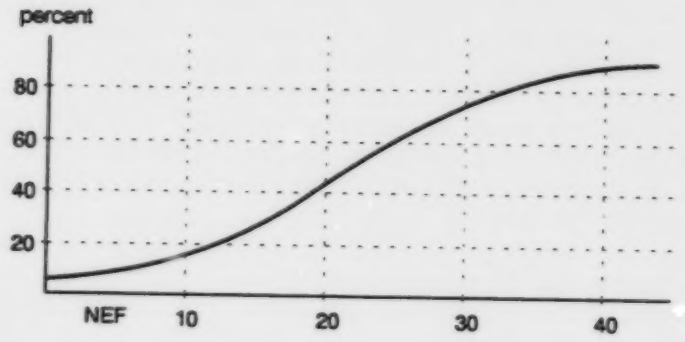

Figure 5

Australian Department of Health studies of noise annoyance indicate that negative attitudes toward the airport, airlines and the aircraft industry significantly increase the level of reported annoyance. Respondent apprehension of air accidents further amplifies these effects. Both findings suggest that noise annoyance is multidimensional, and that successful noise management strategies do not concentrate on acoustics alone. Instead significant benefits may derive from aggressive community relation campaigns to enhance the airport's image and alleviate fears about safety. These findings point to the limited application of dose response analysis in the design of noise management strategies. It is not enough to know how many residents are likely to demand reductions in noise; it is necessary to understand the characteristics of their demands.

A careful selection of a noise management strategy requires consideration of approaches that respond to the most important determinants of the public's dislike for airport noise. For example, noise management can emphasize noise attenuation or scheduling of noise production. In comparing strategies, management should know whether the sound pressure level of noise events is more disturbing than the number of events. Therefore, it is important to document the "technology" of noise strategies, by identifying what aspects of noise they manage, and how these correlate with the demands for noise management by the public. Section 5.2 uses these technology terms to characterize current noise management strategies.

SECTION 4
MEASURING THE NOISE PROBLEM

Measurement of the noise problem means quantifying the relationships that are important in formulating a noise management strategy. Management must initially determine how significant the noise problem is for the airport. If noise is a problem, then it should ascertain the aspects of noise that are most annoying to the airport's neighbours. Each piece of information contributes toward the formulation of a noise management strategy.

Measurement of relevant quantities involves several methodologies. Dose response analysis of the results of annoyance surveys provides an indication of how many people consider themselves seriously affected by noise. Coupled with a qualitative assessment of how responsive regulators and government are to demands for quiet, this information indicates the extent of external pressure for noise management.

Several methods can provide insight into the dimensions of a noise problem at an airport. Noise complaints are a simple expression of demand for quiet. Management can relate complaint frequencies by regression analysis to characteristics of noise such as sound pressure level and number of events. The results will indicate whether noise attenuation or scheduling would reduce noise annoyance more effectively.

Noise annoyance surveys can be expanded to elicit information about the features of noise that respondents find most annoying. Figure 6 presents two questions that Australian researchers have used to study various aspects of noise annoyance. The results of such a survey can present a complete multidimensional "picture" of the noise response for a particular airport. Management can use this analysis to correlate its strategies with those aspects of noise that people find most disturbing.

Experimental methods can also be used to investigate the nature of noise annoyance. British researchers exposed subjects to a controlled experiment that varied the number of noise events and their loudness over a one-hour period. They asked respondents to say how annoying various combinations were. The results allowed them to calculate the relative importance of the two factors to respondents' annoyance.

Evaluation of alternative noise management strategies requires estimates of the costs and benefits. One way to calculate the value of increased quiet involves measuring the effect of noise on real-estate values. Considerable analysis using a technique called hedonic price estimation indicates that noise does reduce residential real-estate values. Estimates of this impact range from 0.4 percent to 1.1 percent per decibel. In practice, a house that sells for $100 000 would sell for between $78 000 and $92 000 if airport noise in the area increased by twenty decibels. The discount measures the value of quiet to homeowners.

Questions that Examine the Dimensions of Noise Annoyance

Please indicate whether or not you are bothered by each of the following aspects of aircraft noise. *(Check one box for each).*

	Yes	No	Don't know
1) THE LOUDNESS OF THE NOISE	☐	☐	☐
2) THE LOW ROARING SOUND OF THE ENGINES	☐	☐	☐
3) THE HIGH-PITCHED WHINE OF THE ENGINES	☐	☐	☐
4) THE TIME THE PLANE TAKES TO PASS OVER	☐	☐	☐
5) CHANGES IN THE SOUND OF THE ENGINES	☐	☐	☐

For each of the following activities, please indicate whether or not you find they are disturbed by aircraft noise. *(Check one box for each).*

	Yes	No	Don't know
1) CONVERSATION	☐	☐	☐
2) WATCHING TV (i.e., TV FLICKER)	☐	☐	☐
3) LISTENING TO TV, RADIO OR MUSIC	☐	☐	☐
4) SLEEPING	☐	☐	☐
5) RELAXING	☐	☐	☐
6) READING OR STUDYING	☐	☐	☐
7) ENTERTAINING INSIDE	☐	☐	☐
8) OUTDOOR RECREATION	☐	☐	☐
9) OUTDOOR WORK (gardening, home maintenance)	☐	☐	☐

Figure 6

Source: DWG Research Associates Ltd., *The Management of Airport Noise*, TP 10118E, Report to Transportation Development Centre (1990).

Management can use surveys to estimate the value of quiet. A survey technique called contingent valuation questions respondents about how much they would be willing to pay to increase the amount of quiet. This technique has been used extensively in the evaluation of strategies to reduce water pollution.

SECTION 5
CURRENT STATE OF NOISE MANAGEMENT

5.1 Introduction

Noise management strategies are employed at airports in Canada, U.S.A., Europe, Japan and member countries of ICAO. Noise abatement, control and exposure strategies vary from country to country, within a country and from airport to airport. In the United Kingdom, Hong Kong, Australia and New Zealand, aircraft noise is not a cause for action at law. With the exceptions of France and Japan, there have been very few lawsuits filed in any of these countries with respect to noise damages. There have, however, been many statutes, acts and other legislation established to protect individuals from noise in the United States.

No country has a formal noise policy, and only the U.S. has stated that aircraft noise is a problem requiring action. Many countries have Acts that are designed to deal with any noise problem, including aircraft noise. The two significant exceptions are Japan and Germany, which have several laws aimed specifically at aviation noise. Thus, few countries have explicitly stated, like the U.S., that noise is a problem and resources are to be used to address the problem. There is an implicit statement in the various Acts and Statutes. Responsibility for noise rests with the national government via the Aviation or Aeronautics Act. The area of common and significant fragmentation of responsibility is land-use planning and zoning. It is here that local economic interest can, and does, conflict with airport, community and national interests.

Meeting the problem of airport and aircraft noise requires local airport noise compatibility programs, aircraft operational procedures and other innovative noise management strategies. Improvement of the noise environment surrounding an airport demands constant monitoring of the needs of the community, the airport users and the airport management. Therefore, airport noise abatement and mitigation strategies and policies adopted by the airport proprietor depend on a number of different factors. These include the level of airport activity, the type of aircraft service offered, the ownership of the airport, the existing and future population densities of the airport environs, and the political climate of the community.

In Canada the noise standards for aircraft are expressed in terms of ICAO Annex 16, and aircraft are said to meet Chapter 2 or 3 requirements. In the U.S., FAR Part 36 establishes noise standards as a certification requirement for aircraft. Stage II and III aircraft certified in the U.S. are approximately the same as aircraft termed Chapter 2 and 3 under the ICAO delineation.

5.2 The Airport Setting

A noise strategy is a specific investment that yields a return. It is specific in the sense that it attenuates or mitigates one or more of the characteristics of noise, and the return is gauged

in terms of effectiveness. This may be measured by the number of noise complaints or by the increase or maintenance in aircraft movements in the face of past opposition of neighbouring communities. It would seem reasonable that the airport proprietor would invest in these strategies in order of diminishing returns.

The ability to generate a return will depend on the physical characteristics of the airport setting and the traffic characteristics. Certainly, noise problems are not confined to airports currently suffering from inadequate capacity. Capacity problems have been incorrectly identified as the principal problem at airports – at many airports noise is the dominant and controlling issue. Figure 7 illustrates a framework for a typology of airports that addresses the issues just raised.[4]

Airport Typology Framework

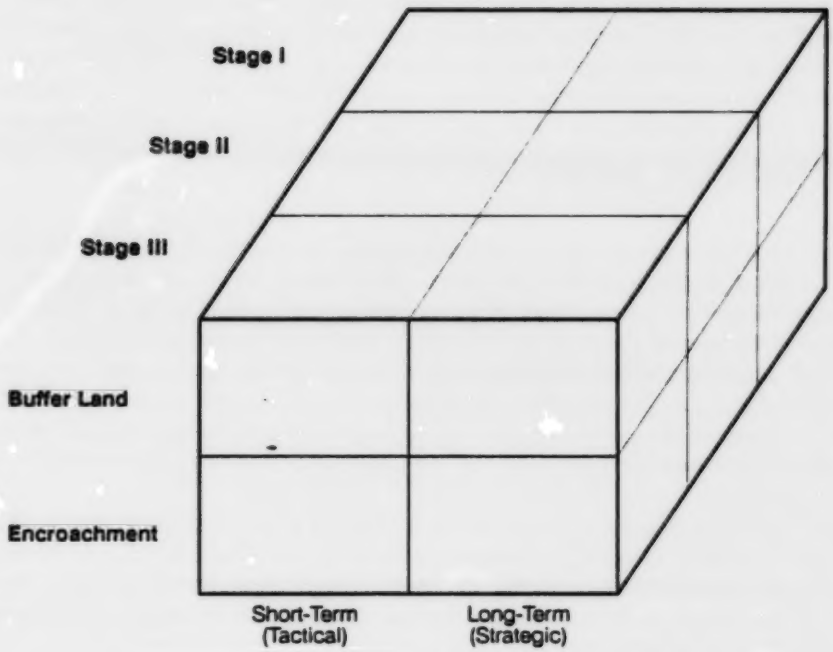

Figure 7

[4] *This typology is developed in detail in Chapter 6 of DWG Research Associates Ltd., "The Management of Airport Noise", TP 10118E, Report to Transportation Development Centre, Montreal (1990).*

Three important dimensions affect the noise management program typology. First, the setting of the airport, interpreted in a broad sense – an airport situated within an urban area or with adjacent residential areas has less freedom than one surrounded by a buffer zone (e.g., Mirabel, Halifax, Edmonton International and, to a lesser extent, Vancouver International). The encroachment by residential areas affects both the number and the type of noise management strategies that can be effectively introduced, as well as the return on those strategies. The setting of the airport affects both the costs it imposes and the benefits it conveys. Both are important in the selection and evaluation of noise strategies.

Second, the stage of the airport in the planning cycle – this can be determined by the nature of demand (scheduled vs charter traffic, type and size of aircraft) and the volume-capacity ratio (the evolution of the airport in terms of maturing towards full capacity utilization). The stages of the planning cycle can be seen to represent thresholds. When the level and character of the traffic changes, a new set of problems emerges and requires a new set of strategies. This dimension permits airport managers to identify the subset of strategies that will address emerging noise issues most effectively. It also provides a planning tool for airport managers, enabling them to anticipate problems and to develop solutions. It forces the manager to identify the nature of demand, which is important for evaluating the benefits as well as the costs of alternative strategies.[5]

Third, the distinctions between short-term and long-term planning – these are represented in Figure 8. Short-term strategies focus on behaviour used to meet immediate problems, and can be altered relatively easily. Long-term strategies have the effect of altering expectations, resulting in a ratchet effect of reduced noise capacity. The following characteristics should be used to classify noise abatement procedures:

Short-term	**Long-term**
• behavioural	• structural
• non-capital action	• capital action (e.g., build runway)
• may alter expectations	• alters expectations with ratchet effect

Consideration of these three factors can help airport managers to define the environment in which they are operating.

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5 This dimension also focusses on the special issues and problems associated with hub airports. Hubs create banks of flights, and thus a peaking phenomenon will occur at various points throughout the day as banks arrive and depart. These banks can alter terminal arrival and departure procedures, thus causing a new set of noise problems created by Single Event Noise Exposure Level (SENEL) and constancy (of visual sightings). The routing changes result in considerable problems because they are new, there is a physical proximity (which triggers noise complaints) and the difference between aircraft noise and ambient noise is large although the mean level of aircraft noise is not considered to be high. Finally, one or two airlines dominating a hub can make the implementation of strategies difficult.

Short-Term and Long-Term Strategy Selections

	SHORT-TERM PLANNING [1]	LONG-TERM PLANNING [2]
UNCONGESTED AIRPORT Low Volume-Capacity Ratio	• Cumulative Noise Energy [3]	• Cumulative Noise Energy • Event Frequency
CONGESTED AIRPORT High Volume-Capacity Ratio	• Event Frequency [4] • Cumulative Noise Energy	• Event Frequency

[1] Short-term indicates non-capital actions (noise abatement procedures, etc.).

[2] Long-term indicates capital-related actions (runway construction, noise insulation, plans, etc.).

[3] Cumulative noise energy indicates any one of the various metrics that measure 24-hour noise output.

[4] Event frequency indicates the number of audible overflights in a designated area.

Figure 8

5.3 Effects of Strategies on Noise

Figures 7 and 8 provide airport managers with a context for the selection and implementation of a noise abatement or mitigation strategy. Tables 3, 4 and 5 present a comprehensive description of the alternative noise strategies available, the circumstances in which they may be appropriate and their probable effect in terms of cumulative and single event noise measures. Table 3 can be termed "strategy identification", Table 4 "strategy impact" and Table 5 "strategy evaluation".

Table 3 presents a matrix divided into three columns. It depicts the relationship between sources of noise problems, strategic areas for solutions, and strategies. The far right column, composed of several sub-columns, specifies the source of the noise problem. The first column identifies the various solution areas. The airport manager will select an area on the basis of jurisdiction, airport context (see Figures 6 and 7), other airport objectives and available resources. More than one area may be chosen. Once the solution area is specified, the set of strategic actions can be selected.

Table 4 relates noise management strategies to several aspects of noise that influence noise annoyance. Having selected the set of *available* strategies from Table 3, management can use this table, in conjunction with analysis of noise annoyance for a particular airport, to select the most effective strategies. The effectiveness of the noise strategy will depend on the objectives of the airport manager and the particular characteristics of the noise that have generated the need to implement a noise strategy.

Table 5 summarizes the benefits, effectiveness and costs of the noise management strategies listed in Table 4. The manager can use this information to evaluate the cost-effectiveness of each strategy. The following example demonstrates the application of the three tables to the planning of noise management strategies:

An airport manager has received complaints from residents regarding the noise from overflying aircraft. Recently, the number of complaints has risen, because the airport is being used for training by a local airline. What are the alternatives open to the manager? First, the manager must consider the context of the airport, its current level of congestion and the value of the training flights to the community. If the airport is underused and the airline contributes to employment and income in the community, there are two (conflicting) objectives for the manager – to keep the airline at the airport, and to satisfy the concerns of the adjacent communities.

Reference to Table 3 under Training Flights identifies a set of alternative strategies. There are twenty-one alternatives, but some can be eliminated since the manager wants to keep the airline at the airport. The strategy may be to select a short-term path to meet the immediate concerns of residents and to work at some long-term solutions that are agreeable to all – airport, community and airline. The manager is aware that as traffic grows, the airline will at some point be forced to move its training flights to an alternative site or to move them to less convenient off-peak times. The manager selects strategic actions 1, 7 and 12 to be considered for immediate implementation and actions 17 and 18 for introduction over the long term. The first three strategies will be considered for this example.

Table 4 provides an indication of the effects of each of these strategies. Strategy 1 can be found under 4.2 – Rotational Runway. The table indicates that such a strategy reduces both single event and cumulative sound levels and duration and significantly reduces outdoor, sleep and indoor interference. Strategy 7 (preferential flight track, under 4.3) has precisely the same attributes as Strategy 1 while Strategy 12 – Alter Glide Slope or Intercept (4.6) – has much less effect in most areas.

A more detailed evaluation of the costs and benefits of these strategies is contained in Table 5. Referring to 4.2 (in Table 5) benefits, costs, noise reduction and comments are provided. Rotating runways (Strategy 1, from Table 3) generally results in noise levels being averaged rather than reduced and, therefore, the stated benefit of this strategy is to spread the noise to all areas of the community. Costs include additional resources for air traffic control and increased administrative burdens. A potential problem area, identified under

"comments", is the increase in noise in areas not previously exposed to flights. Strategy 7 (4.3 in Table 5) has the benefit of focussing noise in the least sensitive areas and will generally redistribute rather than reduce noise. There can be an exception to noise redistribution if the airport is able to create a preferential flight track over an area with no population. The costs of this strategy include additional resources for air traffic control and administration. It may also result in a minor reduction in available runway capacity. The "comments" column points out that complaints from those faced with added noise because of the concentration of flights are likely to rise. Evaluative information on Strategy 12 (from Table 3) can be found under 4.6 and evaluation would be carried out as above.

This simple example of a set of alternative strategies for a given noise problem illustrates how Tables 3 through 5 can be used to examine the effects of each strategy and to assess each on a common basis. They can also serve to rank strategies on the basis of extraneous criteria. For example, in the presentation above Strategy 1 results in a spread of noise over the community while the outcome of Strategy 7 is a concentration of noise over a specific area.

The tables should not be considered exhaustive and relied on exclusively in selecting noise strategies and developing a noise program. They are designed as guides to assist the airport manager to identify issues, parties and technologies, as well as the benefits and costs of strategies.

Table 3

Noise Matrix

Strategic Area for Solutions		Strategic Action	Source of Noise Problem: Noise from Taxiing	Departure	Arrivals	Landing Roll	Training Flights	Maintenance	Ground Equipment
Airport Plan	1	Change runway location	•	•	•	•	•		
	2	Displaced thresholds			•		•		
	3	High speed exit taxiway	•			•			
	4	Terminal relocation	•					•	•
	5	Isolate maintenance run-ups, use test stand or hush house	•					•	•
Airport and Airspace Use	6	Preferential or rotational runway use	•	•	•	•			
	7	Preferential flight track or modify approach or paths		•	•		•		
	8	Restrict ground movement of aircraft	•						
	9	Restrict engine run-ups or use of ground equipment						•	•
	10	Limit number or type of operations or aircraft	•	•	•	•	•	•	•
	11	Use restrictions, rescheduling or move to reliever airport	•	•	•	•	•	•	•
	12	Alter glide slope or intercept			•		•		
Aircraft Operations	13	Power, flap management		•	•		•		
	14	Limit use of reverse thrust				•			
Land Use Program	15	Land or easement acquisition	•	•	•	•	•	•	•
	16	Joint development of airport property	•	•	•	•	•	•	•
	17	Compatible use zoning	•	•	•	•	•	•	•
	18	Building code provision and sound insulation of buildings	•	•	•	•	•	•	•
	19	Property noise notice		•	•	•	•	•	•
	20	Purchase assurance		•	•	•	•	•	•
Noise Management Program	21	Noise-related landing fee		•			•		
	22	Noise budgets		•	•		•		
	23	Noise monitoring		•	•		•	•	
	24	Noise Measurement							
		NEF or Ldn		•	•	•	•		
		SENEL		•	•	•			
		Behavioural Noise Index	•	•	•	•	•	•	•
	25	Establish complaint mechanism	•	•	•	•	•	•	•
	26	Establish value for noise	•	•	•	•	•	•	•
	27	Establish noise capacity	•	•	•	•	•	•	•

Table 4

Impact of Noise Strategies on Single-Event and Cumulative Noise Levels

Noise Characteristics	Sound Level	Sound Duration	Flight Frequency	Outdoor Interference	Sleep Interference	Indoor Interference
Strategy						
1.1 Restrict ground run-up	⇓ △	⇓ ↓	◊	▽ △	⇓ ↓	▽ △
1.1.2 Barriers	↓	⇔ △	◊	↓	↓	↓
1.2 Restrict training time	⇓ ↓	↓	⇓ ↓	⇓ ↓	◊	⇓ ↓
1.3 Noise fees	⇓ ↓	▽ △	▽ △	▽ △	⇓ ↓	▽ △
2.1 Zoning	◊	◊	◊	⇓ ↓	⇓ ↓	⇓ ↓
2.2 Sound insulation	⇓ ↓	⇔	◊	◊	⇓ ↓	⇓ ↓
2.3 Building code changes	⇓ ↓	⇔	◊	◊	⇓ ↓	⇓ ↓
2.4 Noise exposure notice	◊	◊	◊	⇓ ↓	⇓ ↓	⇓ ↓
3.1 Land purchase	◊	◊	◊	⇓ ↓	⇓ ↓	⇓ ↓
3.1.1 Relocation	◊	◊	◊	⇓ ↓	⇓ ↓	⇓ ↓
3.2 Easement	◊	◊	◊	◊	◊	◊
3.3 Runway extension	▽ △	△	◊	▽ △	▽ △	▽ △
4.1 Preferential runway	⇓ ↓	⇓ ↓	◊	⇓ ↓	⇓ ↓	⇓ ↓
4.2 Rotational runway	⇓ ↓	⇓ ↓	◊	⇓ ↓	⇓ ↓	⇓ ↓
4.3 Preferential flight tracks	⇓ ↓	⇓ ↓	◊	⇓ ↓	⇓ ↓	⇓ ↓

Table 4 – continued

Noise Characteristics	Sound Level	Sound Duration	Flight Frequency	Outdoor Interference	Sleep Interference	Indoor Interference
Strategy						
4.4 Maximum safe climb	▽ ↓	△	◊	▽ ↓	▽ ↓	▽ △
4.5 Reduce power on departure	▽ ↓	△	◊	▽ ↓	▽ ↓	▽ △
4.6 Increased altitude descent	▽ ↓	△	◊	▽ ↓	▽ ↓	▽ △
4.7 Displaced threshold	↓	△	◊	△	△	△
4.8 Limit reverse thrust	↓	↓	◊	↓	↓	△
4.8.1 High speed taxiway	△	△	◊	▽ △	▽ △	▽ △
5.1 Limit number of operations	⇓	⇓	⇓	⇓	⇓	⇓
5.2 Limit or restrict hours	⇓	▽	⇓	▽	⇓	▽
5.3 Limit by aircraft type	⇓ ↓	⇓ ↓	↑	⇓ ↓	⇓ ↓	⇓ ↓
5.4 Noise budgets	⇓ ↓	⇓ ↓	↑	⇓ ↓	⇓ △	⇓ △
5.5 Noise monitoring	must be used in conjunction with other noise management strategies					
6.1 Shift to reliever airport	⇓ ↓	⇓ ↓	⇓ ↓	⇓ ↓	⇓ ↓	⇓ ↓

Legend:

cumulative noise decrease ⇓
cumulative noise minor decrease ▽
cumulative noise no effect ◊
cumulative noise constant ⇔

SENEL decrease ↓
SENEL minor decrease △
SENEL no effect ◊
Flight frequency may increase ↑ or decrease ↓

Table 5

Noise Management Strategies: Benefits, Reduction, Costs and Comments

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
1.1 Specify area and time for ground run-up and engine maintenance	eliminates noise at most annoying times	varies 5 -10 dB	administration and construction	does not interfere with active runway hours 22:00–08:00
Barriers	directs sound	up to 10 dB near airport	construction	physical as well as psychological effect
1.2 Restrict times for training	shifts noise to less sensitive time	reduces both SENEL and cumulative noise	redistributes cost to noise generators, loss of local income	effective since eliminates low overflight and repetitive procedures
1.3 Noise fees	provides incentive to fly quiet and purchase quiet aircraft, provides income for abatement program	reduces SENEL and cumulative noise, reduces overall noise level 1.5 dB (Hanscom Field MA)	cost to carriers of operating and fleet costs, also monitoring and administration costs (identification of offenders)	popular in Europe and Japan (some in U.S.), used as revenue source not penalty fee in some cases
2.1 Zoning	safeguards present and future compatible uses of airport environs for all environmental impacts	minimizes number of residents exposed to high-impact noise level	Master plan, administrative, divided interests balance needs of community and airport users	define compatible and non-compatible land use, problem of jurisdiction and conflicting interests
2.2 Soundproofing	community remains cohesive, no moving or relocation, reduces heating costs	reduces all noise in interior by 10-25 EPNdB but 0 for exterior	materials, manpower, administrative framework; costs shared among levels of government	residences in high noise impact area, Ldn 65 or higher

Table 5 – continued

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
2.3 Building codes	creates physical structure to meet noise levels with no modification in later years	interior up to 25 EPNdB over normal construction	materials, manpower, airport management, construction costs, and for justifying the alteration of building codes	requires officials to cooperate
2.4 Property noise exposure notices	all parties realize property status and expectations of existing and future noise levels	none	administrative	does not reduce noise, does provide a type of insurance for both airport and environs
3.1 Land purchase or relocation	reduces population exposed to noise, compromise between community needs and airport requirements	noise level is not reduced but number of people exposed to noise is reduced	varies with land values but is expensive, used in 40 NEF (70 Ldn) demolition, reconstruction and relocation	purchase of compatible and non-compatible land and conversion require local, state FAA and airport cooperation
3.2 Easements or purchase assurance	protects airport for continued use	none	10-20% of appraised land value	quieter areas and noise abatement measures affect the use of this procedure, not considered effective
3.3 Runway extension or construction	increases airport flexibility, can reduce noise impact of some operations on the community	varies with the proximity of the residential area, can be 5-20 dB	master plan, EIS, construction, design and possible land purchase	shifts noise sources away from affected area

Table 5 – continued

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
4.1 Preferential runway	increased use of runway resulting in less annoyance on average	varies, Logan estimates decrease of average aircraft noise of approximately 1 dB	air traffic control, monitoring systems and costs, system design may reduce capacity	may have a variance due to weather effects, may be seasonal
4.2 Rotational runways	provides equal share of noise to all areas of the community	increase in some areas and decrease in others, usually directed at averaging noise levels	air traffic control computer monitoring, and airport administration	can create problems in areas with noise increase
4.3 Preferential flight tracks	concentrates noise over less sensitive land use and least number of people, most benefit over natural barriers	no reduction only redistribution, LAX 90-95% night aircraft noise eliminated	airport air traffic control, monitoring and tracking system, longer flights, may marginally reduce capacity	problems with weather and prevailing winds, people suffering noise increase react
4.4 Maximum safe climb	reduces noise for communities 5-10 miles from airport, reduction in fuel use benefits operating airline	both single event and time exposed to noise level are reduced, result depends on type of aircraft, up to 5 EPNdB	monitoring system, airline procedures, pilot training and workload, aircraft characteristics and safety factors	an aircraft operating procedure dependent on pilot training, airline and aircraft
4.5 Reduce power thrust on climb out	noise impact is reduced for close or proximate parts of community	up to 5 EPNdB but the SENEL decrease depends on the specification of the aircraft	pilot training and workload, air traffic control, monitoring system and staff	an operating procedure dependent on a number of factors as above

Table 5 – continued

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
4.6 Increased altitude descent	population under flight path 2-4 miles from airport benefits most	0-10 EPNdB, does not affect high-noise areas	pilot workload, air traffic control, navigational aids	approach steeper than 3 degrees claimed unsafe due to sink rate
4.7 Displaced runway threshold	accrue wholly to residents bordering runways	reduction at the runway site from 0.9-4.6 dB	navigational aid, pilot workload, air traffic control	depends on aircraft operation and type of aircraft
4.8 Limit reverse thrust on landing	residents proximate to the airport benefit most	both SENEL and cumulative noise are reduced but can't be measured in INM model	runways may have to be lengthened, may affect safety	can increase landing roll, value affected by noise on surrounding runways
Highspeed taxiway	clears traffic, use in place of longer runway	can increase airport capacity	construction cost	
5.1 Limit the number of operations	can have effect of reducing cumulative noise although used in limited capacity and high-density cases	can result in a reduction in total noise but depends on the noise characteristics of the airport fleet	monitoring systems, cost to airlines and public, affects scheduling	high-density rules apply at four U.S. airports and Pearson
5.2 Limit operations to certain hours	impact on the community is 100% but only during designated time period	100% reduction if there is complete closure, 2-3 dB at medium to large airports	airline services and schedules disrupted, cargo movement costs rise, and airport capacity reduced	limitations preferred to closure, need balance of commerce and noise impact, time windows important

Table 5 – continued

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
5.3 Limits based on aircraft specification level	introduction of quiet aircraft, establishes noise threshold acceptable to community	affects both SENEL and cumulative noise, quiet engine gives 10 EPNdB reduction on approach and departure	airline fleet cost, monitoring system, pilot awareness, penalties	airport specific and can impose costs on others in the system
5.4 Noise budgets	can cap or reduce noise level, can allow increase in number of operations	total cumulative noise level maintained at desired level	administration, fees and penalties	
Logan	fixed noise level and increased ability to serve passengers	noise level capped and may decrease if carrier substitutes Stage III for Stage II aircraft. Logan has reduced noise per seat index from 77.95 in 1986 to 76.92 in 1989	administration and monitoring	Logan's Stage III fleet percentage increased from 43.9% in 1986 to 53.4% in 1989
Denver	sets cap on noise for a given period, generally six months	sound energy was reduced 20.02% from noise cap average for 6 months June to December 1987	administration and monitoring	same as Logan
Jackson Hole	can fix cumulative noise level and still increase service	maintains total noise level and reduces SENEL	move to quieter aircraft	the program is governed by the technology of the time

Table 5 – continued

Noise Strategy	Benefits	Noise Reduction	Costs	Comments
5.4 (cont'd) Santa Monica	encourages quiet flying by all, even quiet aircraft	actual SENEL is fixed by category of aircraft, total cumulative noise has declined 4dB	administration, monitoring system, education	forces quiet flying by everyone
5.5 Noise monitoring equipment	pilot education provides accurate measure of actual noise level, not certified noise level, induces quieter flying even for quiet aircraft	control mechanism, community can identify desired noise level and can identify violators	purchase and installation of equipment, staff and administration costs	measures the success of various strategies
6.1 Shift to reliever airports	relief to densely populated areas, spreads economic benefits		significant cost of logistics for passengers and cargo	requires careful monitoring before the move to the reliever, i.e., educate the community

SECTION 6
RECOMMENDATIONS

The results of this project suggest the following observations and recommendations about noise management.

1. The following four general objectives of noise management strategy should be given equal weight.

Provide benefits in reasonable proportion to the costs households incur. Although aircraft noise in residential areas is an economic cost, noise management planning must recognize that steps to abate noise also involve economic costs. Steps to manage aircraft noise in urban areas should aim to balance the benefits derived from noise abatement with the costs of abatement initiatives. Spending $10 on noise management for every $1 in benefits is no more justifiable than devoting insufficient effort to managing the problem.

Target solutions appropriately. Some neighbourhoods may be more seriously affected by the frequency of overflights than by cumulative noise energy. Such communities would benefit more from flight restriction than from insulation. In other communities the reverse may be true. Noise management should measure the source of noise problems and target programs accordingly.

Share the costs of noise management strategies equitably. The benefits of airport capacity usually exceed associated noise costs. The recipients of these benefits should finance the costs of reducing any negative externalities.

Distinguish short-term from long-term initiatives. Measures to reduce noise exposure may be effective in the short term. They are likely to be less effective in the long term as growth leads event frequency to emerge as a dominant source of property depreciation, annoyance and other costs. Managers at highly congested facilities will need to consider radical steps, including compulsory purchase of lands within specified noise contours or airport relocation.

2. Noise valuation should be the basis for noise management strategies.

Legal actions to reduce airport noise often focus on its economic consequences. The question of value arises when compensation is sought. But noise management has largely ignored the question of value as a basis of policy. How much is a householder willing to pay to avoid the annoyance associated with aircraft noise? How is this value relevant to the practical concerns of establishing noise management strategies?

Research shows that the economic cost of aircraft noise from the viewpoint of households and housing markets can be quantified. These findings suggest the following:

- financial compensation programs represent a practical and a publicly acceptable approach to noise management;
- airlines and others have an incentive to help finance such compensation programs; and
- the management of "old" noise and "new" noise should be distinguished in the planning process since the effects of noise level changes on housing markets are measurable.

3. Noise measures are not an end in themselves, but a means of defining noise exposure areas within which to analyse the economic costs of noise.

A noise measurement system should have the following characteristics:

- It should contain a technical metric that provides not only the noise exposure on an "average" day but also some measure of the variance in the measure with changes in the constituent parameters such as traffic mix and meteorological conditions;
- It should be behaviourally based. It should measure people's and markets' responses to noise, not just noise itself;
- It should be multivariate, accounting for the various independent aspects of noise that influence people's and markets' response to noise.

Therefore, the preferred noise measure in the short term is SENEL, and NEF should be used to describe the noise environment. This description should be attached to any proposed project, as it places the onus on the project development to show how noise will be mitigated. The use of SENEL provides a specific and concrete acoustical measure that the abstract NEF does not. It also shifts the onus away from zoning regulators, who rely on "abstract" information in making land use decisions and policy.

4. An airport has a noise capacity just as it has an operational capacity.

The idea of noise capacity is central to the solution of the noise problem. It is the measure of the total amount of noise that the airport community is willing to accept. It depends on the solution to two problems.

- the development of a behavioural noise index that establishes the community valuation of quiet, the costs of changing the amount of quiet and the community's willingness to accept such change; and
- the development of a market device that results in a negotiated definition of the noise capacity of the community and a mechanism to allocate that capacity efficiently.

Current NEF and Ldn measures do not provide a measure of this capacity. Airport capacity is currently being given to the airlines at prices that are well below market and do not reflect the marginal social cost of providing airport services and, in particular, runway services. The true value of capacity has not really been established and the economic need for expansion at some airports is biased.

5. There are tradeoffs in the selection of noise management strategies, apart from the direct costs involved. The following factors must be considered in developing workable strategies.

Political precedent versus effectiveness. While financial compensation might be the most equitable and efficient approach, governments might wish to avoid establishing a precedent of cash compensation for the costs imposed by public projects.

Fairness versus efficiency. Consider a household that located near an airport in full knowledge of the noise levels. Consider a second household that locates near an airport that subsequently expands. On economic grounds compensating the second householder could be justified by the traffic growth he or she did not anticipate. Despite the merit in this argument, fairness issues will diminish the perceived value of purely economic policies. Fairness versus efficiency tradeoffs also bear on the policies regarding those incurring large noise effects versus those incurring smaller effects.

Effectiveness versus simplicity. While segmented and targeted steps might maximize effectiveness, the need for simplicity and administrative ease could lessen the perceived value of targeting.

6. The most appropriate approach to solving the noise problem is financial compensation.

Financial compensation offers the fairest and most efficient means of managing the noise problem. Compensation should mirror costs imposed in the five categories listed below. Those who value quiet highly will use compensation payments to insulate or to help finance moving. Those who obtain greater value from other forms of consumption will use compensation payments accordingly. This approach leads to the greatest satisfaction for those involuntarily exposed to unwanted aircraft noise.

In a ranking of three alternative approaches to noise management – noise reduction, noise mitigation and compensation – the most effective is likely to be compensation since individuals vary widely in their annoyance and concern with noise. Those with great difficulty will insulate (i.e., mitigate) while others will use compensation differently to compensate their losses. Noise mitigation provides the second most effective approach. If Stage III aircraft reduce noise substantially, the focus of noise management will shift to flight frequency effects. If management uses artificially capped growth to reduce noise, the economic costs in lost productivity will far exceed the economic benefits of noise reduction.

7. The ranking of strategies in meeting the goals of noise management should be based on the proportional contribution to noise cost.

Listed below are five factors that span the range of the social and economic effects of noise.

- *Depreciation Costs*. Householders expect to incur property depreciation costs between two to six percent of market value. The actual amount varies by the type of property and its noise contour.
- *Lost Householder Surplus*. Homeowners "induced" to move by higher noise levels incur these costs.
- *Annual Noise Annoyance Costs*. Management can determine these costs from willingness to pay for studies.
- *Moving Costs*.
- *Insulation Costs*.

Noise management strategies can be compared in terms of these cost factors. The optimal mix of initiatives minimizes total noise costs per $1 of noise management expenditure.

8. The airport is a community asset, not simply a cost to the community.

The direct and indirect benefits resulting from the airport operations must be publicized. The airport must market itself and become involved with joint ventures and economic development.

9. Community relations programs are vital to effective noise management programs.

- Making the public aware of the noise tradeoffs is critical in minimizing the distorting influence of small action groups.
- Anti-noise groups must be assisted in understanding the policy options. This can help diminish political resistance to compensation programs.
- Coalition building with the community promotes cooperative efforts to deal with noise. Simultaneously, it reduces potential obstacles to management's exercise of its responsibilities.

10. An effective market must be created so that noise suppliers can compensate noise recipients.

This institutional device, designed to overcome the failure to develop a market, has the following characteristics:

- It provides a mechanism to meet changes in the aviation demands of the community and reconcile these with the demands of other constituencies in the community.
- It forces the airport users to recognize that noise is a property right and is therefore a cost. The cost is currently paid in an indirect and inefficient way.
- There is nothing in this approach that requires public monies to be used. On the contrary, the private capital of the airlines should be used to pay for the noise capacity that they consume.
- It suggests the airport and the community have grown together so the encroachment is not necessarily asymmetric as is generally argued.
- It requires an agreement on what the problem is and what the objectives are before moving to a solution.
- It establishes noise capacity, which is not necessarily equivalent to runway capacity.
- Different noise strategies produce economic value within the community.
- Pricing noise not only provides an incentive for quiet flying but creates an incentive for the airline to be more imaginative in increasing operations within the existing noise capacity.

It is understood that each airport has specific noise management problems. No two airports are alike, but the obstacles they face have common features as well as unique attributes. In developing strategies, managers must consider the main "players" and the airport environment, the particular needs and requirements of the airport and the potential conflict in management objectives. This handbook provides a framework for the "self-definition" necessary for effective noise management.

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These technical reports are combined in one volume and annexed to the copies of TP 10118E in Transport Canada's Main Library in Ottawa and TDC's Library in Montreal.